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White Pine Blister Rust

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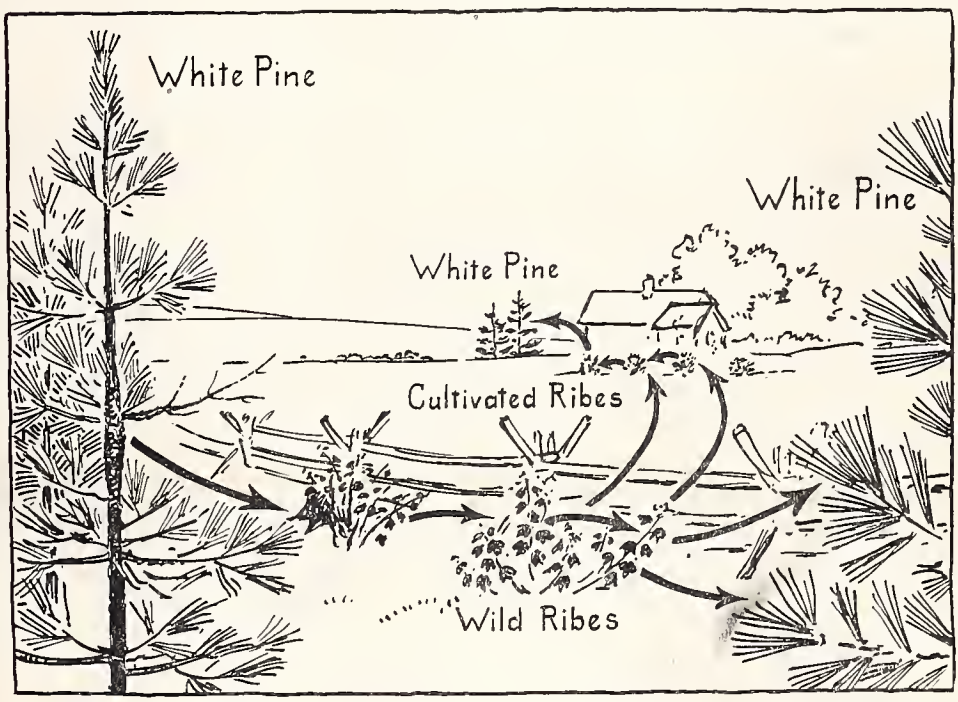

Diagram Showing Natural Spread of Blister Rust from White Pine to Ribes (Currant and Gooseberries) and from Ribes to White Pine.

C. G. JORDAN, *Secretary of Agriculture*

R. H. BELL, *Director, Bureau of Plant Industry*

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SUMMARY

The White Pine Blister Rust came into America from Europe on importations of nursery stock of white pines about 1906.

It is now firmly established on the native white pines in America.

It attacks only five-needled pines, working in the bark of the twigs and branches and causing a girdling of the tree. It soon kills young trees but affects older trees more slowly.

The disease does not spread from one pine to another; infection on pine must come from the alternate hosts, the currants and gooseberries (Ribes spp.)

All wild and cultivated currants and gooseberries are attacked by this rust but the cultivated black currant is by far the most susceptible.

The spore stage on Ribes which can cause disease on pines can spread only short distance; hence the removal of currants and gooseberries from the immediate neighborhood of pines gives ample pine protection.

WHITE PINE BLISTER RUST

By W. A. McCubbin,
Bureau of Plant Industry

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BLISTER RUST DISEASE IN EUROPE

The White Pine Blister Rust is considered to be a native of Europe, where it formerly lived on the native Swiss stone pine *(Pinus cembra)* without, however, seriously damaging that host. About 200 years ago the American white pine *(P. strobus)* was introduced from America into Europe, and within the last century has been extensively planted in European forests[1]. About 50 years ago the blister rust was found to be attacking these pines and it has now become so prevalent that it seriously endangers the future prospects for this valuable timber tree.

INTRODUCTION INTO AMERICA

It was on nursery seedlings of white pines that the disease found its way to our continent. Owing to cheap labor in Europe these pines could be grown, shipped, and sold to us at a price lower than the cost of raising them here. A considerable trade of this nature resulted and several millions of these seedlings of white pines were imported into the United States and Canada from France, Holland, Belgium and Germany. The greater part of these importations

[1]Spaulding, U. S. D. A., Bur. of Pl. Ind., Bulletin 206, 1911, p. 18.

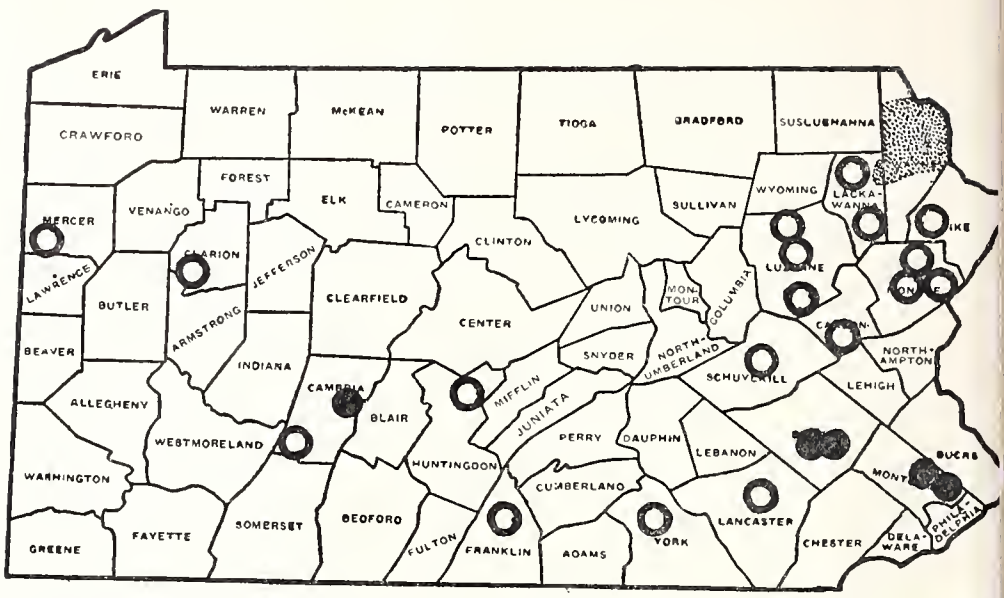

Fig. 1.—Map of the blister rust situation in Pennsylvania. Circles indicate pine plantings from imported stock where the disease has never been found; black circles, similar plantings in which blister rust was found and destroyed. The shaded portion includes all the area of the state known to contain rust on pines or Ribes at the end of 1925.

took place during the period 1906-1909, and in these years, if not earlier, the rust disease came in unnoticed on the young pines and was established on our continent.

The blister-rust disease was first found on currants at Geneva, New York, in 1906, and the source was traced to a nearby nursery pine. Prompt action by the authorities resulted in stamping out this outbreak and it was not until 1909 that other cases appeared in the same State as well as in Connecticut.

During the intervening years scouting has been carried out much more extensively, and at the end of 1926, the blister-rust disease was known to be present in all the New England States, and in New York, Pennsylvania, Delaware, New Jersey, Ontario, Quebec, Michigan, Wisconsin and Minnesota; an outbreak has also been found in the Pacific Coast Region.

THE PENNSYLVANIA SITUATION

In Pennsylvania, scouting for rust disease began in 1916, and in that year a careful inspection was made of all white-pine plantations started from stock originating outside the State. A similarly careful inspection of these pines was conducted by the Pennsylvania Department of Agriculture, Bureau of Plant Industry, each year from 1916 to 1922, and in the case of pines which came from suspicious

sources several inspections were made each season. As a result only five cases of blister rust were found and in every instance as fast as they were discovered the trees were destroyed before the blisters had burst and distributed the spores.

Owing to this prompt and thorough inspection the disease did not become established in Pennsylvania as it did in other states by infection spreading locally from imported pines, and until 1921 no case of the rust on Ribes (currants and gooseberries) was reported within the State. It was to be expected that the disease would gradually work its way down from the badly-infested regions north of us,

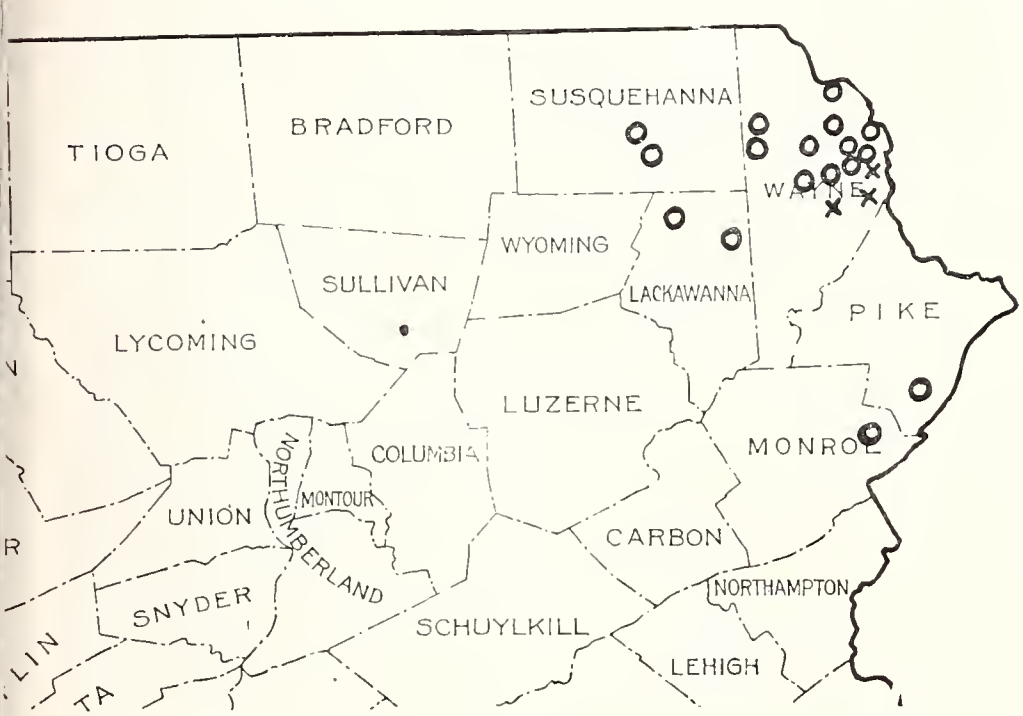

Fig 2—Map of the northeastern portion of Pennsylvania showing the location of all blister rust infections found up to the end of 1926. Circles indicate Ribes infection and crosses rust on pines.

and in each of the years, 1917 to 1921, scouting on Ribes was carried on in the northern tier of counties along the New York border. No sign of the disease was found until in September, 1921, when Mr. S. B. Detweiler, of the Federal Bureau of Plant Industry, reported the finding of the Ribes stage on black currants at Equinunk in Wayne County, just inside the State line. Further scouting in that vicinity in the same month by the Pennsylvania Department of Agriculture disclosed scattered infections, mostly on black currants, in three townships in Wayne County (Manchester, Lebanon, and Damascus). In addition, one case of pine infection was found on the

bank of the Delaware River at Callicoon, in Wayne County. (Fig. 1).

In succeeding years up to and including 1926 the rust does not appear to have spread southward or westward to any appreciable extent. Warren, McKean, Potter, Tioga and Bradford are apparently quite free from it, and none has been found in Erie County. In Wayne County a careful survey in 1925 indicated an infestation practically no greater than in 1921 and there is every reason to think that further spread southward will be slow and difficult, though it is almost certain that this spread will occur in time.

GENERAL NATURE OF THE DISEASE

The fungus which causes this disease is a "rust," and like several other rusts, the wheat rust for example, it spends parts of its life on two different hosts, or to speak more correctly, on two sets of hosts, of which certain species of the genus *Pinus* include the one set, and the various species of the genus *Ribes* the other. The stage on pines is known as *Peridermium strobi* Kleb., and is found only on those pines which have their needles in bundles of five (white pines). Of the fourteen recognized species of white pines, the blister rust is known to occur on eleven: *Pinus strobus, P. aristata, P. monticola, P. excelsa, P. peuce, P. lambertiana, P. strobiformis, P. flexilis, P. cembra* and *P. koraiensis*[1]. Of these, the common white pine, *P. strobus,* is the only one that occurs naturally in Pennsylvania. A few of the other species such as the Swiss stone pine, *P. cembra,* are used to a small extent for shade or ornamental purposes. It may be noted in passing that the five-leaved pines alone are susceptible, and that the two or three-leaved species including the Austrian pine, the Scotch pine, and the jack pine of our northern forests, are not subject to the disease.

The Ribes stage has long been called *Cronartium ribicola* (Fisch. de Waldh.). It is known to occur on twenty-six species of the genus *Ribes,* among which are included all the thirteen American wild currants and gooseberries as well as all cultivated currants and gooseberries. Among these the common cultivated black currant *(Ribes nigrum)* is affected most seriously.

Since the action of the fungus is materially different on its two sets of hosts, it will be necessary to discuss the disease on each separately.

[1]Spaulding, Perley; U. S. D. A., Bulletin 957, February 6, 1922.

THE DISEASE ON THE PINE

Early Stages

In the pine the fungus lives in the bark of limbs and twigs. It was formerly thought that entrance was gained by way of wounds or breaks in the bark, but later research[2] indicated that the chief method of infection was by way of the so-called "short shoots," the small projections to which the bundles of leaves are attached. The later work of Clinton[1] clearly established the fact that the fungus enters through the leaves and then grows down into the limb through the basal short shoot. Wound infection may occur, but it is estimated from a large number of observations that at least ninety per cent of the pine infections take place by way of the leaf fascicles (Plate II, Fig. B).

The conditions following infection vary considerably according to the vigor of the host. Generally speaking, if the tissue of the host is well nourished and active, the fungus acts as a stimulant and induces a local swelling. On the other hand, if the pine limb is weakly, the invaded tissue may be killed without noticeable enlargement. Infections which occur on sickly trees or on shaded, poorly nourished lower branches are likely to result in the death of the tissue (Plate III, Fig. A & B).

The effect on the short shoot varies in the same way. It may be entirely killed and may turn brown or be cast off before its neighbors; a dead fascicle conspicuous among its living fellows, with or without a circular area of dead bark about its base, is often an indication of an early stage of the disease. Again some of the leaves in a fascicle may be killed while the rest remain alive, and in many cases none of the leaves are killed. In vigorous limbs this last condition is likely to happen; here the short shoot becomes swollen and bulbous, and since the growth stimulation apparently retards the normal casting of the shoot, many early infections can be located by noting the presence of one lone fascicle, which has remained after all the others have fallen (Plate II, Fig. B). These abnormal characters in the short shoots thus provide a feature of considerable value in diagnosing early stages of the disease.

As the fungus progresses into the barky tissue or cortex of the limb it either kills the tissue or stimulates it so that a swelling results. In older limbs or trunks of trees where the cortex is already quite thick, or in limbs which are lacking vitality, this swelling is often barely noticeable, but in small and vigorously growing

[2]McCubbin, W. A.: Phytopathology, Vol. VII. No. 2. April, 1927.
[1]Clinton, G. P., Bull, 214, Connecticut Agr. Exp. Sta., September, 1919.

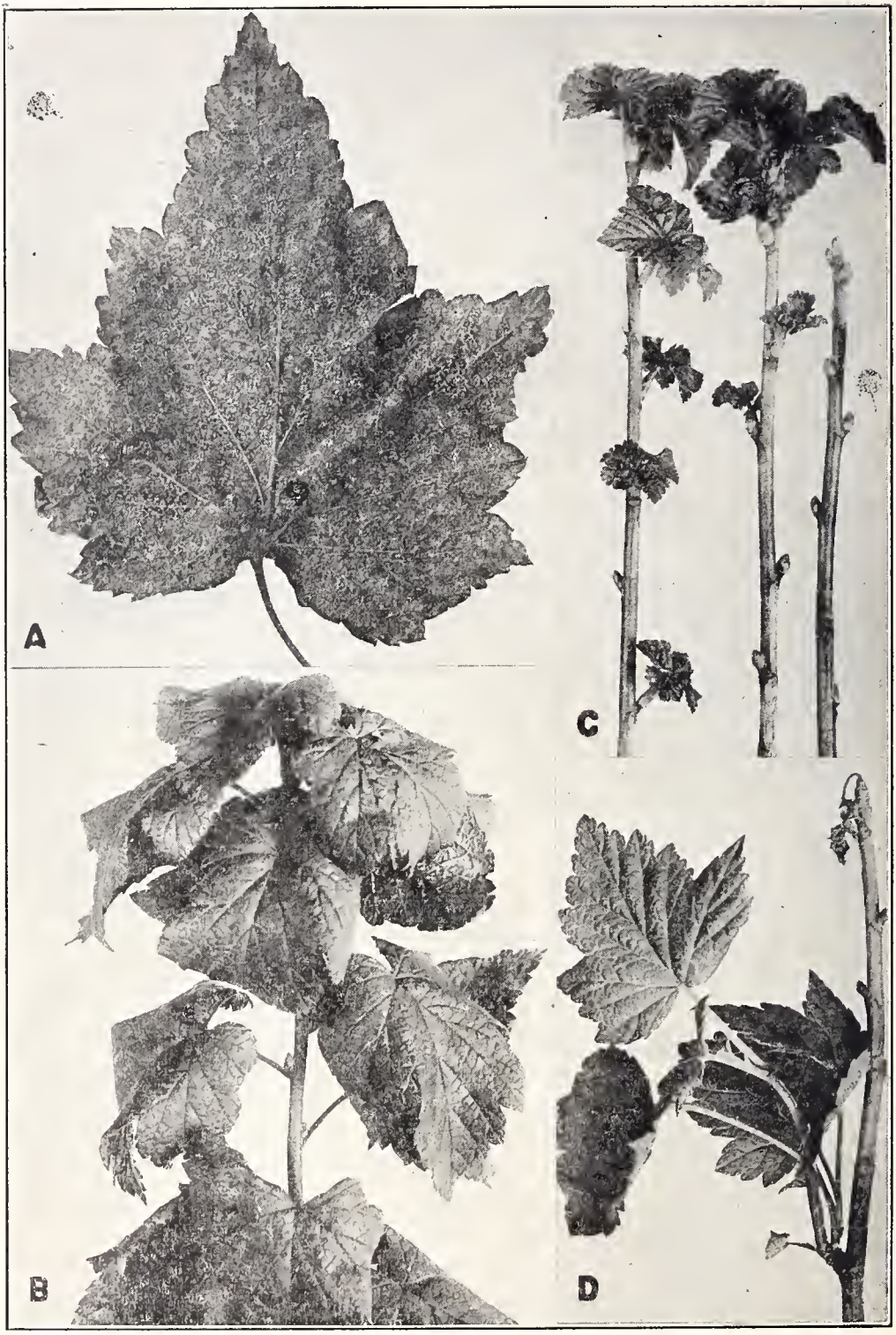

PLATE I:

A—Black currant leaf covered by the spore-horns.

B—Normal black currant foliage, Oct. 20.

C—Rust has defoliated the shoots and the winter buds have grown; also Oct. 20.

D—Winter killing of canes such as are shown in C.

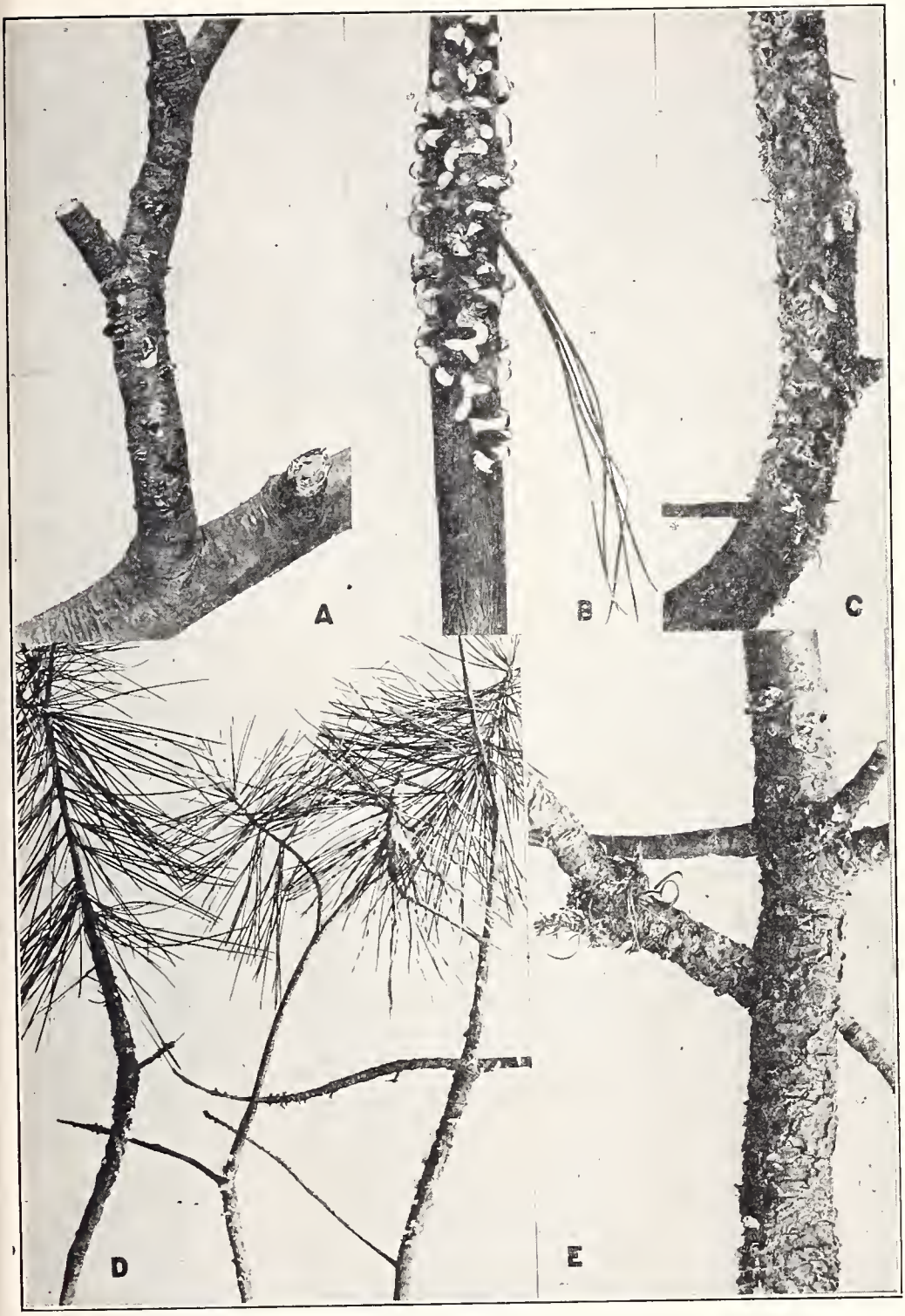

PLATE II:

A—Early stage of blister rust on pine limbs, showing swelling and pycnial droplets.

B—Blisters on a pine limb just before bursting. Infection evidently took place through the retained leaf fascicle.

C—Infected pine limb on which the blisters have burst.

D—Three smaller infections, all starting from side shoots now dead. The typical swelling is evident.

E—Condition of cracked and roughened bark persisting after blisters are shed.

branches it is very conspicuous. Ordinarily these swollen parts are spindle-like, that is, thick in the center and gradually tapering towards the ends (Plate II, Fig. D). Usually the bark of these swellings has a sickly, yellowish color and this feature is of the highest value in determining suspected cases of the disease, enabling one to distinguish cases of blister rust from dropsical conditions of the bark, excessive growth resulting from injuries, and other abnormal conditions that might be confused with the swelling caused by the rust fungus. Swelling without discoloration of this kind may be doubtful, while on the other hand bark discoloration is often met with unaccompanied by swelling, but when both the swelling and the sickly color are present together the probability of blister-rust infection is very strong.

The swelling and discoloration noted are likely to spread with great regularity from the point of infection so that in early stages of most blister-rust cankers one may be able to make more certain of the diagnosis by finding the wound, a small dead bark area, or abnormal leaf-fascicle in the centre by way of which the fungus made its entrance.

In later stages the presence of swelling and discoloration are exceedingly useful features in determining doubtful cases. Dead areas in the bark of limbs are often caused by the rust fungus, but since there are so many other causes that may bring about killing of strips or areas of the cortex, the mere presence of dead bark is of little diagnostic value. However, the true blister canker usually shows both swelling and discoloration in the adjacent living tissue and since both these features ordinarily are not found around dead areas produced in other ways, a means is provided for determining this class of cankers with some degree of certainty. The bark in pine shoots so often is overgrown by black incrustations of fungi, that any discoloration which might be present is obscured. In such cases one may bring out the discoloration more certainly by moistening and scrubbing the bark.

Production of Pycnia

Frequently on these discolored swellings may be seen small drops of a sticky, sweet liquid that have been pushed out through the bark (Plate II, Fig. A). These drops are not resin as one might suppose at first glance, but are a liquid exudation caused by the fungus. In some cases they are clear and transparent, while in others they are clouded or "milky" in appearance due to the presence of immense numbers of very small spores (pyncospores). These "pycnial

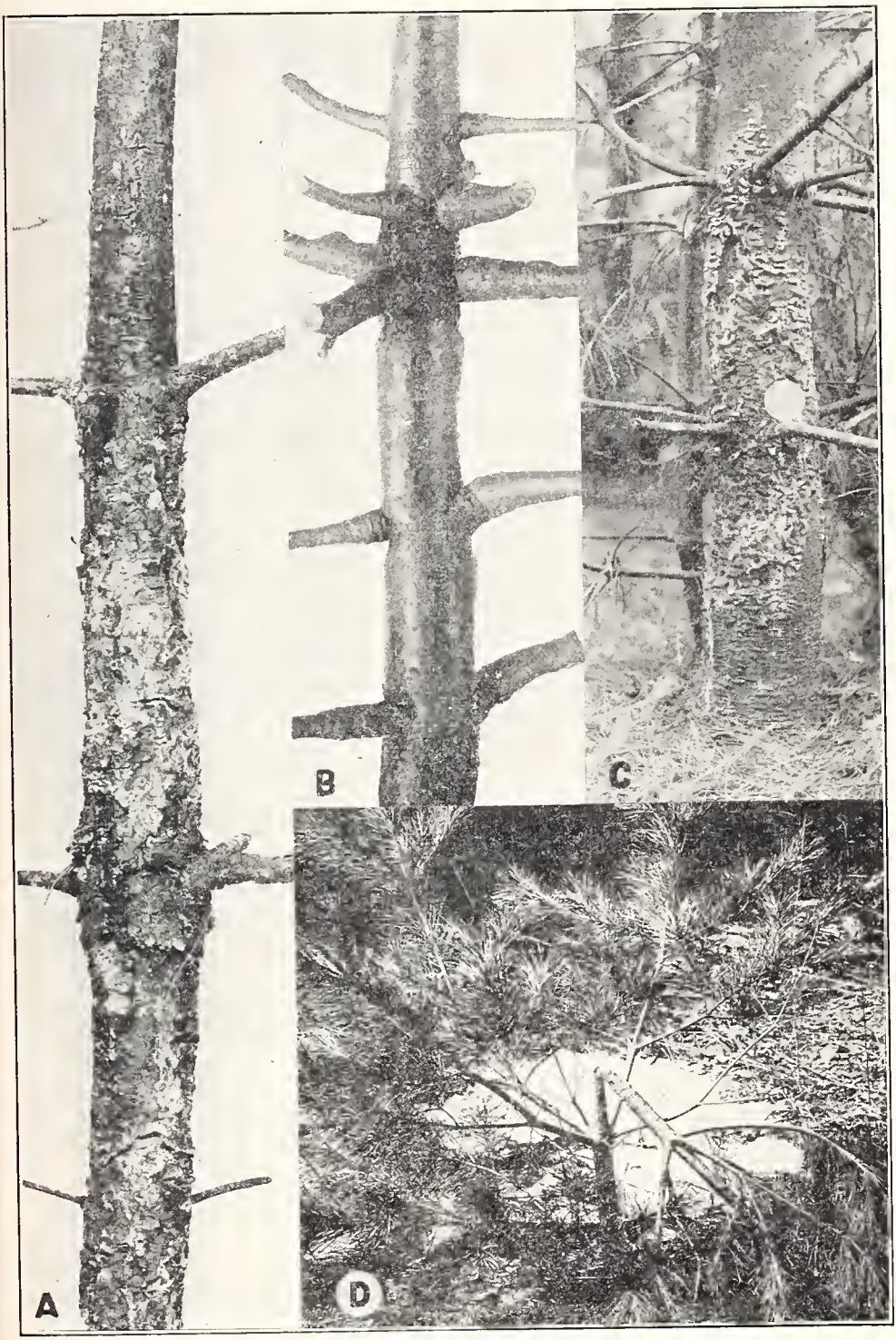

PLATE III:

A—An old blister rust canker with resin exudations.

B—Several blister rust infections with swelling and bark killing symptoms prominent.

C—A Typical case of blister rust on a young white pine tree.

D—Seedling white pine girdled by blister rust,

spores" generally are considered to be a degenerate spore-form, and it is thought that they are not capable of spreading the disease. In any case, as they dry up in the drop, they would have little chance of being carried about, although insects often feed on the sweet liquid of the drops and thus might spread the spores to a small extent.

The Blisters

After the so-called "swelling stage" has lasted for a more or less indefinite period, blisters *(aecia)* are produced from the swellings which give the disease its name of "blister rust." These blisters appear only for a short time in spring, most of them coming out during May, though early or late cases may be met with in April or June. They are about the size of a match-head or larger. When first pushed out through the swollen bark they are of a light orange color but soon fade, until finally they become almost white (Plate II, Fig. B). They vary in number from one or two to several hundred, according to the size of the branches from which they arise. Each blister consists of a mass of orange-colored, dust-like spores enclosed within a delicate membrane. The covering of the blister is ruptured so readily by wind, rain or the brushing of branches that in a few days after it is formed it is broken up, the mass of spores is liberated, and nothing remains but white remnants of the delicate membrane, a few scattered spores, and the slit-like openings in the bark in which the blister was borne (Plate II, Fig. C). Later, in the summer, the ragged remains of the blister coverings and the few remaining spores disappear entirely, and for the rest of the season the bark-slits only are visible. (Plate II, Fig. E).

As these bark-scars made by the blister are recognizable several years afterwards, they provide a sure and certain means of diagnosing the disease on pine limbs. Once blisters have been produced on a branch, the resulting scars remain as certain evidence of the disease for many years, so that whatever the difficulty in recognizing the early stages, there can be no uncertainty after the formation of the blisters.

As time goes on, the bark about these scars splits and cracks until the condition shown in Plate II, Fig. E, is reached; the somewhat enlarged limb with rough, cracked bark, shown in the illustration, is thoroughly characteristic of this stage of the disease.

Usually blisters are produced only once on a given portion of the limb, except in vigorous branches with thick bark on which blisters may be produced a second or even a third time. Afterward the limb

may die from this point up, or it may still live, though often the part above the affected place will be sickly. The fungus, however, remains alive and gradually spreads into uninfested portions of the limb adjacent to the blister canker, both above and below if the limb is still alive, and below only if the upper part is dead. Such extensions are accompanied by the usual swelling and discoloration, and blisters will appear on these freshly-invaded sections in due course (Plate II, Figs. D E). The fungus thus creeps slowly but surely down the branch, each year producing a crop of blisters if conditions are favorable, and at the same time advancing into the adjacent bark. When a larger limb is reached, the rust fungus creeps both upward and downward as before until the limb is girdled and dies above the point of attack, after which it can only work downwards. In due time the trunk is reached and the tree is destroyed.

Points by Which to Recognize the Blister Rust

The various features outlined provide a number of useful marks which help one to locate infections that otherwise might escape observation by being more or less obscured by masses of foliage. Shrunken dead areas on the trunk, often noticeably by reason of copious, white out-pouring of resin; a dead limb conspicuous among its fellows, especially one with roughened, swollen or cracked bark; a small tree with an unhealthy yellow top, or a top which is close and bushy in appearance with short needles much bundled together; a branch with light, sickly foliage on an otherwise healthy tree; a leaf-cluster yellowed, browned and dead, but still remaining on the shoot after the others have fallen; similarly a leaf cluster that is still green and remains alone after its neighbors are cast;—all are outstanding features which may lead the observer to cases of the disease that might otherwise escape notice.

Symptoms Likely to be Mistaken for the Blister Rust

1. The pine woolly aphis (*Chermes pinicorticis* Fitch) often causes a roughening of the bark and slight swelling of the limb, especially toward the upper end of a year's growth. The white cottony material produced by this insect may be mistaken for remnants of the blisters. Often the bark on these areas is over-grown by a black fungus.

2. Twigs are often killed by other causes, such as weather, drought, wounds, insects, and excessive shade. Sometimes these are difficult to determine but the true rust infection usually produces discoloration and swelling in the adjoining living tissue.

3. Sunscald often occurs on young pines. The scalded sides of the limb tissue are pale and sickly in color but without swelling.

4. Drought injury in 1916 and 1923 resulted in the death of many young pines, and in the death of the terminal portions of others. None of the usual signs of the disease at the junctions of the dead and living portions was present. A similar killing of the terminal shoot is often caused by the pine shoot-moth *(Evetria* sp.).

5. Many trees develop a dropsical condition in which the bark becomes very thick, soft and putty-like in texture. This apparent swelling is uniform on the branch or stems and is without discoloration.

6. Cases of lumpy swellings on pine limbs have been noted. These are usually more rounded and not so spindle-shaped as blister-rust infection, involve the wood as well as the bark, and have no typical discoloration.

7. Rubbing of two branches often causes a yellowing of the bark. The cause should be readily determined.

8. An insect of the borer type often makes a yellowish or discolored streak in the bark which may be distinguished by its wavy course, but regular width.

9. Bleached areas often occur about the bases of leaf fascicles on young shoots. In such cases the short shoot fails to develop or is stunted, and as the shoot grows older, a pale, discolored area without swelling remains. The cause of this condition is unknown but apparently it is not due to blister rust.

10. Lower branches on young pines concealed by leaves or grass and in contact with soil or moist vegetable mold are often somewhat enlarged and bleached. Unless blisters are apparent, such cases are somewhat hard to determine, except by microscopic examination. The recent work of Colley[1] has provided a means of readily demonstrating the presence of the rust fungus in this or other doubtful cases.

General Progress of Disease on Pines

How long does it take the disease to kill a pine tree? What will be its effect on our present pine forests? To answer these questions one must look into what already is known of the progress of the disease on pine branches. Starting with the earliest stage, that of infection, let us follow the course of the disease as far as existing information permits.

[1]Journal of Agricultural Research, Vol. XI, No. 6, p. 28, 1917.

Infection takes place in summer or autumn, but prominent symptoms of the disease do not appear immediately. Under favorable conditions swelling and discoloration of the twig may arise during the ensuing summer, but if the branch is poorly nourished this symptom may not appear until a second season after infection, or even longer. The first production of pycnia accompanies the development of the swollen conditions, and the first blisters appear about the second summer after infection if the limb is vigorous; otherwise the bark tissue may be killed instead of being stimulated, and the fungus may remain alive for many years slowly progressing down the branch without the formation of blisters.

In addition to this slow development of the blister stage, the progress of the fungus downward, even in vigorous twigs, is far from rapid. Very often only an advance of a couple of inches is made in a season. Rarely has it been found to spread farther than about a foot a year. Many blister cankers are known which on good evidence can be shown to have been present on the tree for eight years or more and yet they have involved only a small part of a single branch. It is also quite apparent that the progress of the disease is slower in weak, shaded limbs, or those about to be cast off by natural pruning, than it is in healthy, sappy tissue, such as would be found in young, rapidly-growing trees.

On the other hand because the blister-rust is slow in action it must not be considered harmless. It is an extremely deadly disease. Once established in a tree it practically never dies out, and sooner or later the death of that tree is assured. When one considers that a pine tree requires at least fifty years to reach merchantable size, the leisurely course of the disease takes on a new meaning. Although it requires considerable time to kill the tree, there is plenty of time in which to accomplish its final destruction.

Damage to White Pines

To sum up the present prospects for damage to our white-pine stands one must consider both those pines which are now mature or nearly mature, and also the smaller seedlings which are now springing up, and on which our future supply of this valuable timber will depend.

On older pines.—As regards the older pines, say those thirty years of age and upward, it is highly probable that the disease will not materially affect any large percentage of them before they can be utilized. In the first place the blister-rust is slow in action; since

in most cases the disease starts at the leaf fascicles it will in older trees have to travel a considerable distance down the limb before the vital part of the tree—the trunk—is reached. Then too, in older limbs in ordinary conditions the progress of the disease will be much slower than in the case of young, vigorous limbs full of sap. In a dense stand of pines the lower branches become sickly and die early in life. The disease in older trees therefore must attack the tops or upper branches, and there is reason to think that, owing perhaps to dryness of the air or distance from the low-growing currants, infection does not occur so readily in the tops of trees as it does near the ground. Serious damage might arise in older trees where the disease is so plentiful that it attacks every limb or a large percentage of the limbs, or where it starts in a late-formed branch and thus can reach the trunk in a short time, or where it enters by way of a wound. However, it is probable that such exceptional cases are of comparatively rare occurrence. Even when the disease reaches the trunk of a large tree it may persist there for many years without actually girdling the tree although European writers state that in such cases the fungus soon weakens the trunk to such an extent that it readily breaks off in the wind. According to Spaulding[1] trees 100 years old have been killed (in Europe) but such cases are not common.

From these considerations it would appear that while older trees are likely to be damaged and even killed under certain conditions, the great majority of our larger trees will not be seriously affected by the disease before they are ready to cut.

In young pines.—With regard to young trees the situation is entirely different. They have still a long period of years before they can mature, and during this period even such a slow disease as the blister rust can work immense havoc. They are more subject to infection than older trees, both because the susceptible parts are near the ground and consequently near scattered wild or cultivated currants, and because the greater moisture content of the lower air favors infection. Then again the disease makes more rapid progress in their vigorous, sappy tissues than it does in older wood, while the distance to be covered by an infection before reaching a vital part of the tree is very small compared with that in larger trees. From a consideration of these factors one may conclude that the blister rust is likely to prove disastrous to young white pine and careful observations already strongly bear out this conclusion. Wherever the disease has been plentiful on currants for a few years, young pines nearby have been so badly infested that only a very

[1]U. S. Dept. Agric., Farmers Bulletin 489, p. 8, 1912.

small proportion of them could hope even now to reach maturity. With the passage of time the disease is sure to increase and pine infection will become so frequent that the outlook for future commercial pine stands would be very dark indeed, without some practical method to protect them from infection.

DISEASE ON RIBES (CURRANTS AND GOOSEBERRIES)

The "Pine to Ribes" Stage

The spores from the blisters which are formed in spring on the pine branches are scattered by the wind when the blisters burst. If such spores happen to be carried to *Ribes* leaves they will germinate and thus the fungus will be transferred to its alternate host. Perhaps it would be better to say its other hosts, since this stage of the disease can occur on practically all of the numerous species of wild currants and gooseberries, as well as on all the cultivated currants and gooseberries, including the black, white, and red currants, the flowering currants and both European and American gooseberries. Of all these, the common, cultivated black currant is attacked the most severely.

These "pine-to-*Ribes*" spores from the pine blisters are mostly set free some time in May but signs of the rust on currant leaves usually are not encountered until the first of June or later. The fungus grows into the leaf from the spore and after a couple of weeks there is formed, on the underside of the leaf only, a rust spot, which has its beginning as a small, pale yellow, wafery blister no bigger than a pinhead, but which later becomes somewhat larger, turns a bright orange color, and finally bursts, releasing the enclosed mass of orange-colored spores *(urediniospores)*. These spots always occur on the underside of the leaves, and as these plants habitually turn all their leaves very carefully so that the upper surface faces the light, a considerable number of rust spots may be present on the leaves of a bush without being readily visible unless the leaves are turned over. Experience has shown that the most satisfactory way to look for *Ribes* rust is to turn the leaves with a slow, upward movement of the hand and forearm, examining them as the undersides are uncovered.

After these first rust pustules are produced the fungus may spread into the leaf tissue around them and as it advances fresh rust pustules are formed. The tissue of the leaf in the invaded area either is killed outright or it is badly weakened and turns yellow. This feature is of considerable value in looking for the disease in June. Since the leaf tissue at this early season is thin and soft, the kill-

ing or yellowing of the leaf is so pronounced that it usually shows plainly on the upper surface; hence if small yellow or dead spots are seen on the upper surfaces of the leaves at this season the rust may be suspected and looked for under the leaves. These dead spots and yellow areas are seen so readily when passing among *Ribes* bushes that if any considerable amount of the rust is present it can be detected without resorting to the slow process of turning over the leaves of each bush.

It should be noted, however, that these yellow spots and dead areas soon cease to have any important value in determining the disease. As the season advances the leaf tissue thickens and the rust no longer kills the leaf in definite areas or even causes a yellowing visible from above. Moreover, spots, dead areas, and yellowing are likely to arise later in the season from a number of other causes, such as leaf-spot fungi, insects, wounds, etc., and these may be so numerous as to quite destroy the value of such easily observed features as evidences of the rust. After July 1 little reliance can be placed on such symptoms in detecting the disease, and examination of the under sides of the leaves is necessary.

When the pustules of the rust break open and release the small masses of orange-colored spores within, the wind carries these spores to other currant or gooseberry leaves where, if weather conditions are favorable, they will germinate and infect these leaves. Both from observation and actual experiment it is known that about two weeks are required from the arrival of the spore on a leaf until the new-formed spot produces a pustule with fresh spores. In other words, if a spore from a pine blister starts an infection spot on a currant leaf, in two weeks time the new spores are ready for distribution from that spot. These *"Ribes*-to-*Ribes"* spores are then scattered and start new infection spots on other currant leaves, and at the end of another two weeks there is a second crop of spores from these spots. Thus as the season goes on there is an ever-increasing number of rust spots, and this serves to explain why the disease usually is not severe or plentiful on *Ribes* till August and September. The initial currant spots started in spring from pine blister spores, usually are scattered and few and it requires a couple of months of spreading and multiplying from these isolated spots before the rust becomes generally plentiful.

Moreover, weather conditions greatly influence the spread of spores and the rapidity of reproduction. In order to germinate and successfully infect a currant leaf the spores must have water, and this water must be present for a considerable time. The rust cannot

infect in hot, rainless days and dewless nights but in a summer when there are a number of periods of successive rainy or foggy days, infection will occur readily and an increase of the disease may be expected. This need of moisture for successful infection also explains why *Ribes* in low, wet places are often more badly rusted than those located in higher, and drier situations.

Another point of interest in regard to these spores is the distance they are carried in the wind, which is of course the chief disseminating agent. Observation leads us to think that a majority of the spores are carried only for short distances to the next bush or to a few bushes nearby. Many, however, are carried in gusts or eddies of wind and may travel to the surrounding plantations readily enough, while there is every possibility that some of these are carried in the wind for several miles at least. In a recent paper[1] where the possible spread of these spores in the wind was arrived at by ascertaining the rate at which they fell in still air, it was concluded that when they are swept up into the air, they may travel ten miles or even very much farther under such favorable conditions.

The "Ribes-to-Pine" Stage

While the spores produced from the pustules on currant leaves can infect other currant leaves, apparently they are unable to infect pines. As the season advances, however, the fungus on the currant undergoes some internal change, after which it produces an entirely different kind of spore, one which is capable of infecting pines but not currants.

After this change occurs the small pustules with the masses of orange-colored spores are no longer produced; instead the fungus grows out from the surface of the leaf to form small finger or horn-like projections, orange or reddish-brown in color, about as thick as a pin and about an eighth of an inch long. These "spore-horns" may occur singly, or a few may be clustered in a spot, or if the leaf is badly rusted they may cover the entire under side, giving it a reddish-brown and felted appearance, from which the name of "Felt Rust" for this stage (Plate I, Fig. A), has arisen in Europe. Each of these spore-horns is made up of a mass of several hundred spores *(teliospores)* closely fastened together, and as time goes on each of these sends out a small thread on which are borne from one to four very small, round colorless spores *(sporidia)*. It is these small round spores that are able to infect the pines, but neither they nor

[1]Phytopathology, Vol. 8, No. 1, p. 35, January, 1918.

the stationary spores in the spore-horns from which they arise can infect *Ribes* again.

If one looks at a badly rusted black currant leaf towards autumn, the spore-horns are easily seen, and if the weather has recently been moist each spore-horn will be seen covered with a delicate white, frosty growth (Plate I, Fig. A). This white furry coating marks the development of what may be called "Ribes-to-pine" spores—the small, round, colorless spores already mentioned—which are capable of infecting pines.

The "spore-horn" or "felt" stage of the rust does not appear suddenly all over the currant foliage, but has been found in a few cases toward the end of June, and from this time, a gradually increasing number of infection spots change into the spore-horn condition as the season advances, until by the end of September nearly all of the early "*Ribes*-to-*Ribes*" stage has disappeared, to be replaced by the "*Ribes*-to-pine" stage just described.

The sporidia or little spores developed on the spore-horns are carried by the wind and if they fall on pines are likely to infect the branches and thus bring about the characteristic swelling and blisters already mentioned.

However, observations that have been made up to this time point to the conclusion that these spores are not effective at great distances, since very few pine infections have been found at points more than a few hundred feet from currants. There is evidence that this failure of the sporidia to infect pines except within a short distance from the point of origin on *Ribes* leaves is due mainly to their extremely short life; they have been found to remain capable of germination for a matter of minutes or at most very few hours. The fewness of sporidia produced except under favorable conditions is also a limiting factor in pine infection, while the interposition of a mass of foliage which acts as a screen is also known to be highly effective in hindering the transfer of the disease from *Ribes* to pines.

This feature of the disease is worthy of emphasis because it suggests the only hopeful means that we can employ for growing pines successfully in areas where the rust is now present or may later become established. If "*Ribes*-to-pine" infections can only take place in any considerable numbers when the *Ribes* are close to the pine, it is quite possible to prevent the disease from being commercially damaging by keeping the two hosts separated; i. e., by eradicating

all *Ribes* from the pine plantation and around it for a distance of several hundred feet.

Overwintering of the Rust on Ribes

The view generally held by earlier writers on this disease was that the *Ribes* stage died out each season with the fall of the leaves, and that *Ribes* infection must be started anew each season by spores from pine blisters. There arose from time to time however a number of cases so puzzling that the suspicion of overwintering of the disease on *Ribes* was much strengthened. The first definite proof that this overwintering may take place, was obtained by York and Spaulding, who succeeded in producing the disease on *Ribes* in spring from urediniospores wintered on *Ribes* leaves in the open.[1] The actual occurrence of this overwintering therefore is beyond doubt, but it is generally considered that the cases where this happens under field conditions are comparatively few, and that most of the currant rust actually does die in fall. Still the spread that may result from isolated cases of overwintering makes this feature of the disease of some importance in the possibility of a wider spread from year to year on *Ribes* alone.

Damage to Ribes

What harm does the rust cause to currants and gooseberries? It has been stated already that the cultivated black currant is severely attacked. On wild currants and gooseberries the rust occasionally is severe, especially when these are so situated that early and plentiful infection from some nearby diseased pine can take place, or in swamps and low places where conditions for spread are favorable

On red and white currants and on gooseberries also there is apparently little damage. These species are in general so little affected by the disease that the harm done may be considered as negligible. Very often one can find no trace of the disease on them, even when located adjacent to diseased pines, and where the disease does occur it is usually confined to a few small spots of no commercial importance. In a few cases individual gooseberry and red currant plants have been seen where the rust was rather severe but such cases seem to be extremely rare and in general it is safe to say that as far as cultivated red and white currants and gooseberries are concerned the disease is of very small importance.

[1]Phytopathology, Vol. 8, No. 12, p. 617, December, 1918.

On black currants, on the other hand, the rust is often quite damaging. Many plantings are attacked so badly that every leaf is covered with rust (Plate I, Fig. A) and the whole surface of the ground beneath them is colored with a layer of orange spores. In such cases the leaves die and fall early in the season, instead of remaining on the bushes till late in the fall, as is the habit of this plant.

Symptoms on Ribes Sometimes Mistaken for Blister Rust

(1) Gooscberry leaves which have been torn or punctured by brushing against the spines often develop small brownish ridges or pustules. In these the orange color is lacking.

(2) Scale insects are not uncommon on the leaves, where they appear as minute brownish spots.

(3) Bees sometimes drop masses of orange pollen on currant or gooseberry leaves. These can be distinguished by the ease with which they can be removed as they are superficial and do not grow out of the leaf tissue as do the true rust pustules.

(4) In localities where the soil is highly colored the spattering of rain often deposits small reddish mud spots on the leaves.

(5) On the wild gooseberry there sometimes occurs another rust quite different from the blister rust. It brings about a thickening of the leaf tissue into a noticeable pad in which there are numerous distinct cavities or "cups." This pad-like spot is orange in color also.

(6) Currants and gooseberries are subject to several leaf spot diseases, all of which bring about the death of small areas in the leaf tissue. In one of these sporc pustules of light amber color are produccd, but the orange color so characteristic of blister rust is lacking.

(7) Symptoms associated with the curling and blistering of leaves caused by plant lice are very common but are not likely to be mistaken for blister rust.

SUMMARY OF LIFE HISTORY OF THE DISEASE

A. On Pines

(1) Lives on five-needled pines only.

(2) It lives in the bark of trunks, limbs and twigs.

(3) In the limbs it either kills the bark, or causes local swellings, which are usually spindle-shaped and have a sickly yellowish discoloration.

(4) After a time delicate blisters filled with orange colored spores arise from these swellings in early spring. (April-June)

(5) These spores can infect currants but not other pines.

(6) The fungus lives from year to year on the pine limb creeping slowly downward till the trunk is girdled and the tree destroyed.

(7) Seedlings or young trees are girdlcd and killed rapidly, adult trecs damaged more slowly.

B. On Ribes (Currants and Gooseberries).

(1) Attacks all wild and cultivated currants and gooseberries; cultivated black currants particularly susceptible.

(2) Thc leaves of **Ribes** are affected; few or many small orange rust pustules are formed **on the under sides** of the leaves.

(3) During thc summer spores from these pustules spread the disease to other **Ribes,** but not to pines.

(4) Some time about mid-summer the fungus in the leaves undergoes a change, after which spores are produced on the **Ribes** leaves which are able to infect pines but not **Ribes** again.

(5) The rust generally dies out with the fall of the **Ribes** leaves so that the rust of the ensuing year must be started in spring from some diseased pine.

(6) Damage to all **Ribes** except cultivated black currants is small. On the latter the rust may cause early fall of the leaves and consequently a weakening of vitality.

CONTROL OF BLISTER RUST

The problem of control must be considered from two points of view: (1) measures necessary to prevent the spread of the disease over large areas, and (2) precautions the individual owner may take to protect his pines or *Ribes*. An outline of the measures that have been found necessary to meet the disease in each of these cases follows.

General Continental Control

Since 1913 no five-leaved pines originating in Europe or Asia have been permitted to enter the United States, and all importations of *Ribes* from Europe and Asia have been prohibited since 1917. The danger of further introductions of the disease from abroad being thus removed, the chief feature of the problem of control is to keep the disease from spreading into pine regions where it does not now exist. In order to prevent blister rust passing from the already infected eastern sections over the prairie belt to the Pacific Coast pine regions, a Federal quarantine was established in 1917 forbidding the shipment of white pines or *Ribes* westward beyond a line following the western boundaries of Minnesota, Iowa, Missouri, Arkansas and Louisiana. In Canada a similar Federal quarantine prohibits the shipment of eastern-grown white pines and currants into Alberta or British Columbia.

Since the establishment of this mid-continental quarantine line the blister rust has been found to be well established in British Columbia, Washington and Oregon, so that all hope of permanent protection for the western areas of susceptible pines has vanished. With this change in the national situation the Federal Blister Rust Quarantine was reissued in 1926 and its regulations are aimed largely at prevention of spread by other than natural means into the regions not yet known to be affected. In the eastern United States the chief object to be attained is to delay the spread of Blister Rust southward from the New England States and New York into the long stretch of white pine territory extending from the Lakes region along the Appalachian ridges as far as Tennessee. Since Pennsylvania not only straddles across the northern portion of this wedge-shaped southern extension, but is now at the southward march of the disease, this state will continue to be of strategic importance in the blister rust problem for some years, at least until the disease has crept southward beyond the Mason and Dixon line.

In order to protect the white pines in the southern end of this pine belt as well as to provide similar protection elsewhere, the

present Federal quarantine (No. 63) prohibits shipment of white pines or European black currants from the states where blister rust is present into states still free from it; and the shipment of red currants, white currants and gooseberries interstate is permitted only under a cerificate system which practically guarantees their safety in the matter of spread.

Local Control

The control measures that can be adopted by individual owners, by cooperative effort or by municipal action, all are based on the one fundamental principle: "Keep the two hosts as far apart as possible." This principle takes advantage of what appears to be the weak point in the life history of the rust, i. e., the difficulty with which it passes from *Ribes* to pine over any great distance. The jump from pine to *Ribes* is easily and successfully accomplished, partly because the aeciospores on the pine are numerous and are easily distributed by wind from their elevated sources on pine branches, and partly because the summer spread on *Ribes* provides for the rapid multiplication and wide distribution from a very small initial *Ribes* infection; but in the reverse passage the fungus is far less successful and by separating the hosts for a comparatively short distance the amount of pine infection can be reduced to a minimum. Under average conditions, pines at a distance of three hundred yards are regarded as being safe from a commercial point of view; by which is meant, that a stand of pines at this distance from *Ribes* will in the course of development suffer so little from the disease that the final stand will be satisfactory.

To this general statement several exceptions must be noted. The first concerns cultivated black currants, on which the disease develops so plentifully that they may become dangerous to pines even if they are a half a mile or more away. Another exception must be made to cover cases where the local moisture conditions are especially favorable to the disease, as often occurs in swampy, wet land, or in thickets beside streams. In such cases a sterile zone only three hundred yards wide would probably not give sufficient protection to the pines. The same holds true in places where there are prevailing winds or local air movements, which tend more or less constantly from the *Ribes* to the pines.

With due consideration to all these irregularities the following recommendations are given to owners whose pines have or are in danger of having the disease.

SUGGESTIONS FOR PREVENTION

For Pine Owners

(1) Destroy all *Ribes* (currants and gooseberries) within the pine plantation, and around it to a distance of three hundred yards.

(2) Remove cultivated black currants to a distance of half a mile.

(3) Take the *Ribes* out of swamps and low, wet places for a distance of from three to five hundred yards, depending on their number and the humidity of the place.

(4) Eradicate wild *Ribes* in the spring if possible; wild *Ribes* come into leaf earlier than most plants, and may thus be more easily detected at this period.

(5) In eradication work use the strip method, the men working abreast in the strip each covering a five-to-ten yard frontage. The strips may be marked previously by blaze, by paper, or by any similar device.

(6) Have each strip checked over to see that no plants are left. Check several times if necessary.

(7) Take out all large *Ribes* roots carefully; otherwise new plants will start from the root fragments.

(8) Do not leave *Ribes* plants on the ground, where they will take root and grow readily; they should be *piled and burned* or hung securely in trees or on stumps.

For Farmers' Woodlots

White pine is very valuable now, and will probably increase in value as the years go on. Consequently protection to young pines will be amply repaid in future years. Cut or pull out all wild currants and gooseberries not only from the woodlot itself, but from the surrounding fences and waste places; where there are young white pines these useless wild plants should be regarded as outlaws to be destroyed whenever and wherever they are seen.

For Owners of Ornamental White Pines

It should be always kept in mind that the blister rust does not attack Austrian or Scotch pines, or any other two or three-leaved species, but will be found only on the five-leaved pines. If the disease is present in the district the pines can be safe-guarded by the removal of surrounding *Ribes* (currants and gooseberries) in-

cluding all wild plants as well as the garden varieties and flowering currants.

A pine affected by blister rust may sometimes be saved by cutting off the affected branch, taking care to make the cut a foot or more below the swollen or blister-bearing part. When the infection is in the main stem the tree often may be saved by careful surgery unless the disease has progressed too far around the trunk. The method consists in making a cut clear through the bark entirely around the blister rust canker and at a distance of from two or three inches beyond the outermost visible limits of the cankered tissue. All the bark within the cut is then removed. If all the fungus-bearing tissue has been thus eliminated the wound will heal over in due time without any further development of the disease.

For Owners of Currants and Gooseberries

The only species of currant or gooseberry that is likely to be badly rusted is the common garden black currant. If rust is severe on these for several years it is likely to weaken them to such an extent that they will be unprofitable. If another fruit will answer the purpose equally well, replace the black currant plants with something else as soon as possible. Spraying methods have not given satisfaction. One may as well state frankly that black currants growing in a neighborhood where the rust is present and white pines are numerous, are practically at the mercy of the disease.

For Nurseries Where White Pines are Grown

A nursery pine infected by blister rust is almost certain to start an outbreak of the disease in the new locality where it is set, and thus distribute the rust more widely and more quickly that the slow spread from the north could accomplish in many years. Unfortunately the existence of a period during the first years of infection on the pine when there are no symptoms outstanding enough to disclose the presence of the rust, renders nursery inspection of pines practically valueless. The only conditions under which five-leaved pines can be grown safely, are either in a rust free district, or in a locality where all wild and cultivated *Ribes* are absent, or from which they have been removed to a distance of at least three hundred yards. Even a greater *Ribes*-free zone will be necessary around the young pines, if black currants are grown locally, or where there are conditions of air currants or moisture favorable to the disease.

Is it Safe to Plant White Pines?

The vigorous reforestation movement sponsored by the State Forestry Department that has been started in Pennsylvania will doubtless become more and more extensive and important as years pass, and since the white pine is recognized to be one of our most valuable timber trees, there is sure to arise the question: "Can white pine be planted with a reasonable hope of their reaching maturity without being destroyed by this disease?"

While the disease is to be found at present in only a very limited area of the state it is sure to spread gradually southward in future years. Consequently pine plantings should be undertaken with the understanding that sooner or later before the stand matures it may be exposed to attacks of the disease. If the planting is in a district free from *Ribes,* or if these dangerous hosts can be removed to the required distance from the pines, there would appear to be no reason why pines can not be successfully grown in our state. It is fortunate that the most harmful member of the *Ribes* group, the cultivated black currant, is far less generally grown than in regions farther north, and equally fortunate is the fact that the wild species of *Ribes* are comparatively scarce over large areas of our timberlands. Where eradication of *Ribes* must be carried out to protect local stands of pine, the scarcity of these plants will measurably lessen the cost of eradication.

PENNSYLVANIA DEPARTMENT OF AGRICULTURE

C. G. JORDAN, *Secretary of Agriculture*

R. G. BRESSLER, *Deputy Secretary*

This Department is essentially a service agency created by legislative enactment to deal with administrative, regulatory, investigational, and educational problems which can best be solved through public rather than individual action. The organization provides for coordination and cooperation with the Pennsylvania State College and the U. S. Department of Agriculture. The Department operates through the following bureaus:

ANIMAL INDUSTRY: T. E. MUNCE, *Director and State Veterinarian*

Prevents and Eradicates transmissible diseases of animals and poultry, including tuberculosis of animals in cooperation with Federal Government.

Demonstrates to veterinarians control methods for transmissible animal diseases;

Supervises vaccination for and the prevention of hog cholera, anthrax, black leg and hemorrhagic septicemia;

Protects public from unwholesome meats through ante and post mortem examinations of animals at slaughtering establishments;

Inspects, licenses and furnishes information as to breeding, soundness and conformation of stallions and jacks standing for public service;

Enforces law requiring licensing of dogs and providing for protection of livestock and people from attacks of uncontrolled dogs;

Maintains laboratory for diagnostic research and experimental projects.

PLANT INDUSTRY: C. H. HADLEY, *Director*

Tests agricultural seeds for purity and germination, and enforces State Seed Law;

Inspects orchards, parks, farms, and plant imports for injurious insects and plant diseases;

Inspects and licenses Pennsylvania nurseries, and licenses all dealers in nursery stock;

Makes investigations for the control of injurious insects and plant diseases including field tests of insecticides, fungicides and weed killers;

Enforces laws governing apicultural practices, disease control and housing;

Places and enforces quarantines and carries on eradiction campaigns against insect pests and plant diseases;

Inspects and certifies potatoes for seed purposes;

Maintains collections of insects, plant diseases, plants, and seeds, and identifies specimens.

FOODS AND CHEMISTRY: JAMES W. KELLOGG, *Director—Chief Chemist*

Accomplishes its purpose of protecting Pennsylvania homes against harmful foodstuffs by sampling, analyzing, and bringing prosecution under the laws relating to foods and non-alcholic drinks, including milk, cream, butter, ice-cream, eggs, sausage, fresh meats, soft drinks, fruit syrups, vinegar and kindred food products;

Regulates and issues licenses for the manufacture and sale of oleomargarine;

Licenses and regulates egg-opening plants and cold storage warehouses, maintaining regular inspection and enforcing twelve-month storage limit;

Inspects milk plants and creameries and regulates weighing, testing, buying and selling of milk and cream on a butterfat basis;

Protects honest manufacturers, importers, selling agents and ultimate users of feeding stuffs, fertilizers, lime products, linseed oil, paint, putty, turpentine, insecticides and fungicides, by means of annual registrations followed by inspections, analyses, prosecutions and the publication of the analyses of these products;

Analyzes special samples for residents of the State at the rate of $1.00 a sample for feeding stuffs, lime products and linseed oils.

MARKETS: P. R. TAYLOR, *Director*

Investigates and assists in the marketing of farm products; at present chiefly grain and hay, fruits and vegetables, poultry and eggs, and tobacco;

Compiles and distributes daily market information as to supplies, shipments and prices;

Advises growers on transportation of agricultural products;

Assists cooperative associations and public markets;

Establishes standard grades of farm products and maintains inspection.

STATISTICS: L. H. WIBLE, *Director*

Assembles and disseminates essential statistics and facts pertaining to the agriculture of the State, from monthly reports rendered by hundreds of volunteer crop correspondents, information which assists the producer in his sales and interests all industries which deal with agricultural products;

Cooperates with U. S. Bureau of Agricultural Economics in joint crop and livestock reporting and publishes annual and monthly summaries of the data;

Compiles dates of county and local fairs and assembles data pertaining to their success and results during each year.